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N II and O III line ratios on the Sun

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Abstract EUV emission lines from N II and O III ions are studied for diagnostic applications in the solar atmosphere In order to compute line emissivities, we have considered 15 level atomic model, to set up the statistical equilibrium equations taking account of various physical processes in the line formation We have studied the line emissivity ratios as a function of electron density in the light of the EUV observations being taken from the CDS and SUMER instruments on the spacecraft SOHO We have also discussed the applications of the density-insensitive line ratios for inflight calibration of the spectrometer

Keywords Line diagnostics, EUV emission lines, optically thin plasmas

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1. Introduction

Emission lines from the cosmic plasmas have been the subject of extensive study since the advent of space research for diagnostic application. Because of high temperature of chromosphere-corona transition region and the corona, the elements present there are multiply ionised and are at various stages of ionisation. These ions emit radiations in the EUV range and contain the information on the physical conditions of the emitting region. Analysis and interpretation of these emission (as also absorption) spectra play an important role in understanding the physical properties of the emitting regions.

EUV emission lines from the ions of carbon sequence have been observed in the spectra of astrophysical objects such as planetary nebulae [1] and the solar atmosphere [2]. Diagnostic applications from these ions have been extensively studied [3-7]. N II and O III are the lower ions in the carbon sequence and have not yet received much attention. We have, therefore, taken up these ions for diagnostic studies of the solar plasma. We also discuss the density-insensitive line ratios for inflight calibration of the instruments.

2. Line emissivity and atomic data

The line emissivity per unit volume, per unit time for an optically thin plasma is given by

$$\varepsilon(\lambda_{ij}) = \frac{1}{4\pi} N_j \, A_{ji} \frac{hc}{\lambda_{ij}} \text{ ergs cm}^{-3}\text{ s}^{-1}\text{ sr}^{-1}, \tag{1}$$

where A_{ji} is the spontaneous transition probability and N_j is the number density of the upper level j which can be parametrised as :

$$N_j(X^{+p}) = \frac{N_j(X^{+p})}{N(X^{+p})} \cdot \frac{N(X^{+p})}{N(X)} \cdot \frac{N(X)}{N(H)} \cdot \frac{N(H)}{N_e} \cdot N_e \, . \tag{2}$$

Here, X^{+p} is the p-th ionisation stage of the element X ; $N(X^{+p})/N(X)$ the ionisation ratio of the ion X^{+p} relative to the total number density of the element X ; $N(X)/N(H)$ is the abundance of the element X relative to the hydrogen which may or may not be constant in solar atmosphere; $N(H)/N_e$ is the hydrogen abundance which is taken to be 0.8 for a fully ionised plasma and $N_j(X^{+p})/N(X^{+p})$ is the population of level j relative to the total number density of the ion X^{+p} and is determined by solving the detailed statistical equilibrium equations for the ion.

Thus, the line emissivity can be written as

$$\varepsilon(\lambda_{ij}) = \frac{1.59 \times 10^{-8}}{4\pi \, \lambda_{ij} \, (\text{Å})} A_{ji} \frac{N_j(X^{+p})}{N(X^{+p})} \frac{N(X^{+p})}{N(X)} \frac{N(X)}{N(H)} N_e \, . \tag{3}$$

The line emissivity ratio of two lines emitted from the same ion can, therefore, be expressed as

$$R = \frac{\varepsilon(\lambda_{ij})}{\varepsilon(\lambda_{kl})} = \frac{A_{ji}}{A_{lk}} \cdot \frac{\lambda_{kl}}{\lambda_{ij}} \cdot \frac{N_j(X^{+p})}{N_l(X^{+p})} \, . \tag{4}$$

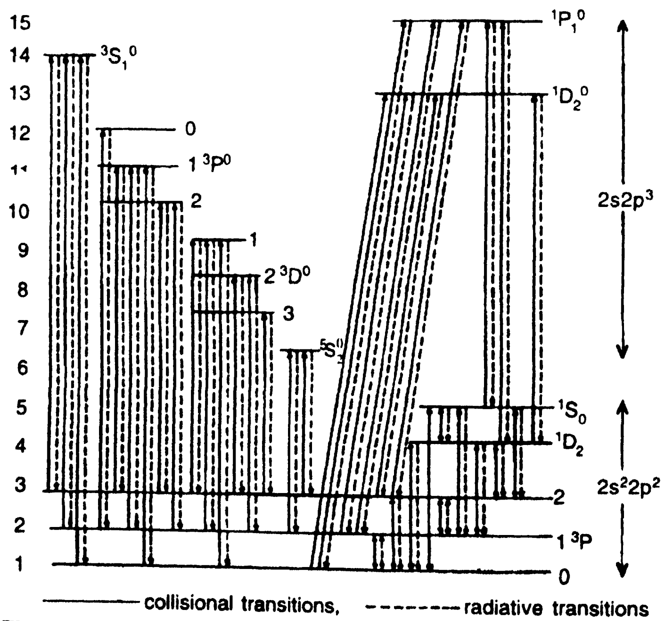

Figure 1. Schematic energy level atomic model for N II and O III lines.

The schematic energy level atomic model comprising the first 15 levels for N II and O III lines is shown in Figure 1. The ground configuration consists of $(1s^2 2s^2 2p^2)$ ^3P, ^1D and ^1S and the higher configuration includes $(1s^2 2s 2p^3)$ $^5S^0$, $^3D^0$, $^3P^0$, $^1D^0$, $^3S^0$ and $^1P^0$ terms. The collisional processes are shown by solid lines while the radiative processes by broken lines.

The atomic data needed to compute the line emissivities are the following : (i) wavelengths, (ii) radiative transition probabilities and (iii) collision strengths. The transition probabilities and the wavelength values have been taken from the tabulation of Wiese *et al.* [8]. The collision strength values have been obtained by extrapolation along the iso-electronic sequence in the following manner. For reasons discussed by Dwivedi and Gupta [6], in the case of forbidden transitions, the collision strengths for Ne V, Mg VII and Si IX from Aggarwal (cf. [9] and references cited therein) were used for extrapolation. For allowed transitions, we have used the Mason and Bhatia [3] values for Mg VII, Si IX and S XI and those provided by Aggarwal [9] for Ne V for extrapolation.

3. Results and discussion

We have shown line emissivity as a function of electron density for N II and O III in Figures 2 and 3 respectively. These lines should be observed with longer exposures by the CDS and SUMER instruments on the spacecraft SOHO. In Figure 4, we have shown the line emissivity

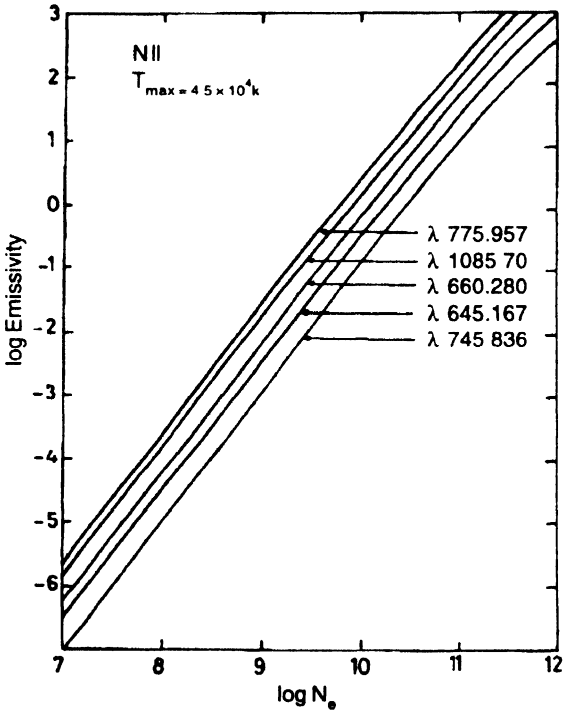

Figure 2. N II line emissivity as a function of electron density at $T_{max} = 4.5 \times 10^4$ K.

ratios as a function of electron density for N II at its maximum ionic concentration temperature $T_{max} = 4.5 \times 10^4$ K and in Figure 5, line emissivity ratios for O III at $T_{max} = 6.5 \times 10^4$ K. We find that the line ratios are sensitive to electron density in the range of less than 10^8 cm^{-3}. Therefore, these line ratios can be useful for density determinations in planetary nebulae. However, the density-insensitive line ratios relevant for solar atmosphere can be useful for inflight calibration of spectrometers.

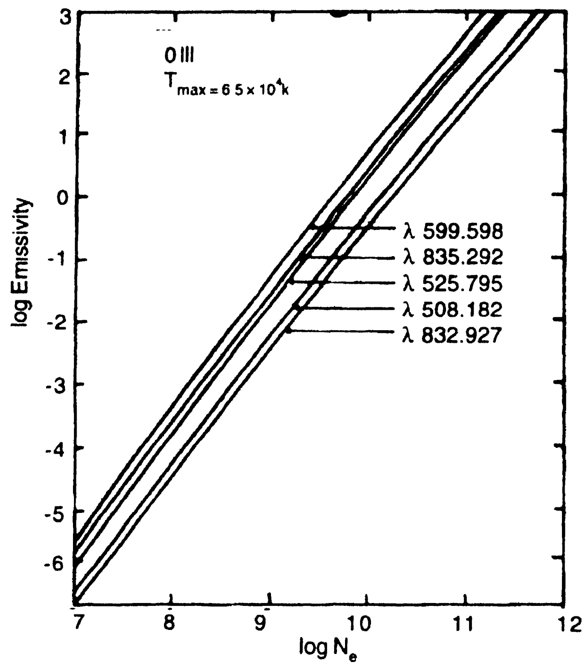

Figure 3. O III line emissivity as a function of electron density at $T_{max} = 6.5 \times 10^4$ K

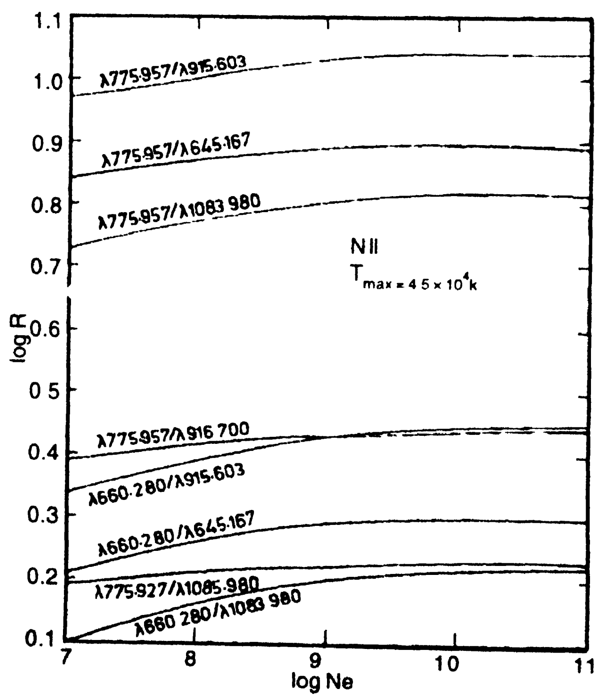

Figure 4. Theoretical line emission ratios for N II ion as a function of electron density at $T_{max} = 4.5 \times 10^4$ K

4. Conclusions

N II and O III emission lines have been studied for diagnostics of solar plasma. Line ratio curves show density sensitivity in the range < 10^8 cm^{-3}, and can be useful for diagnostics of planetary nebulae. Density–insensitive line ratio curves in the relevant N_e, T_e range for the solar plasma can be useful for the inflight calibration of the instruments.

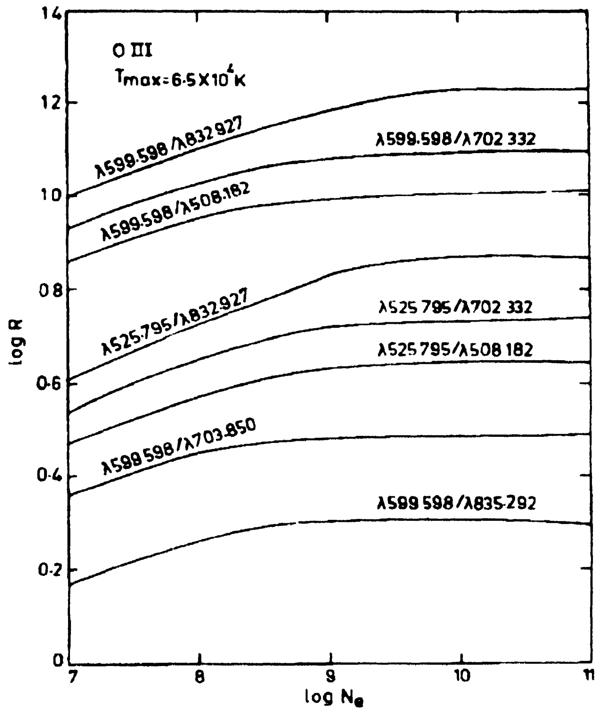

Figure 5. Theoretical line emission ratios for O III ion as a function of electron density at $T_{max} = 6.5 \times 10^4$ K

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